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by Jennifer Patry-Parisien, Jiping Zhu and Suzy L. Wong

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| .. | not available for a specific reference period |
| ... | not applicable |
| 0 | true zero or a value rounded to zero |
| 0* | value rounded to 0 (zero) where there is a meaningful distinction between true zero and the value that was rounded |
| P | preliminary |
| r | revised |
| X | suppressed to meet the confidentiality requirements of the <i>Statistics Act</i> |
| E | use with caution |
| F | too unreliable to be published |
| * | significantly different from reference category ($p < 0.05$) |

Implementation of the indoor air component of cycle 2 of the Canadian Health Measures Survey

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Abstract

Background

The presence of volatile organic compounds (VOCs) in indoor air may have negative health consequences, ranging from mild irritation to more severe illnesses. Indoor air data are required to assess Canadian population exposure to these VOCs.

Data and methods

The 2009 to 2011 Canadian Health Measures Survey (CHMS) included an indoor air component. Respondents who went to the mobile examination centre to participate in the physical measures section of the survey were asked to deploy an indoor air sampler in their homes for 7 consecutive days. Data were collected for 84 VOCs. Control samples that were implemented included duplicates and blanks.

Results

Of the 4 686 indoor air samplers given to CHMS respondents, 4 581 were deployed and returned to the testing laboratory. Data from 3 857 samplers met the criteria for inclusion in the CHMS indoor air data files. Thirteen VOCs had a mean percentage difference between the duplicate pairs greater than 30%. The field and cleaning blank geometric means and medians were lower than 1 µg/m³ for 83 VOCs.

Interpretation

The high percentage of mobile examination centre participants who deployed samplers in their homes, the sampler return rate, and the quality of the data obtained demonstrate the feasibility of relying on respondents to handle indoor air samplers for large-scale collection of residential VOC data.

Keywords

Air pollution, air quality, data collection, indoor air sampler, organic chemicals, survey methods, volatile organic compounds

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Organic chemicals are present in a wide variety of common household products such as paints, paint strippers and other solvents, aerosol sprays, cleansers and disinfectants, air fresheners, and hobby supplies.¹ These products can emit gases known as volatile organic compounds (VOCs) while they are being used, and even when they are stored. Concentrations of many VOCs are consistently higher indoors than outside.^{2,3} In fact, indoor air is the largest contributor of human inhalation exposure to VOCs.^{4,5}

The extent and nature of the health effects of VOCs depend on factors such as the level of exposure and the length of time exposed. The health consequences of VOCs in indoor air can range from mild irritation to more severe illnesses.⁶ At present, however, little is known about the health effects of the levels of VOCs usually found in homes.

Governments worldwide have recognized the need to evaluate the health risks of industrial and environmental chemicals.^{7,8} In Canada, risk assessment and management are carried out under the Canadian Environmental Protection Act (CEPA)⁹ and the Chemicals Management Plan (CMP).¹⁰ A necessary step, of course, is the collection of information about levels of VOCs to which the population is exposed.

Canada's first national survey of indoor VOCs was conducted in 1991 and included 26 VOCs.² More recent regional surveys have measured VOCs in the city of Ottawa³ and in Quebec City.¹¹ However, information about the indoor air levels of many VOCs on the CEPA and CMP lists is not available. In support of the CEPA and CMP, Statistics Canada's 2009 to 2011 Canadian Health Measures Survey (CHMS)¹² collected baseline data on levels of 84 VOCs in residential indoor air.^{2,3,11}

This paper describes implementation of the indoor air component of the CHMS and presents information about response rates and results of field quality control samples.

Methods

Data source

The data are from the second cycle (2009 to 2011) of the CHMS,¹³ an ongoing survey designed to provide comprehensive direct health measures at the national level. The 2009 to 2011 CHMS covered the population aged 3 to 79 in private households. Residents of First Nations Reserves, institutions and some remote regions, and full-time members of the Canadian Forces were excluded. Data were collected at 18 sites across the country from August 2009 through November 2011. Ethics approval for the CHMS was obtained from Health Canada's Research Ethics Board.¹⁴

The survey consisted of a questionnaire administered by Statistics Canada employees in the respondent's home, followed by the respondent visiting a mobile examination centre where physical measures were performed and additional questionnaires were administered.

Participation was voluntary; respondents could opt out or refuse any part of the survey at any time. Written informed consent was obtained from respondents aged 14 or older. For younger children, a parent or legal guardian provided written consent, in addition to written assent from the child (where possible). Detailed information about the content and sample design can be found in the *CHMS Cycle 2 Data User Guide*.¹²

CHMS data are national estimates representing 96% of the household population aged 3 to 79. Of the 8,520 households selected for the survey, 6,465 agreed to participate, and 4,722 took part in the physical measures component at the mobile examination centre, where indoor air samplers were distributed to 4,686 households. Respondents from the remaining households either refused to take a sampler, or because of supply problems, a sampler was not available to give to them.

Volatile organic compound collection

The indoor air sampler selected for the survey was the PerkinElmer Thermal Desorption Sorbent Tube (PerkinElmer, Inc., Shelton, CT, USA), 3.5 inches (89 mm) in length and 1/4 inch (6.4 mm) in diameter. Sampler performance, specifically the VOC uptake rate, was validated for exposure time of 4 to 10 days.¹⁵

Figure 1 illustrates the processing of samplers and approximate timelines. Cleaned samplers were sent from the testing laboratory to Statistics Canada. Each sampler, with two Swagelok hexagonal nuts at each end, was placed in an aluminum container, which also contained a loose gray mesh cap and round polymer cap (white cap). The samplers were packed in a cardboard box and shipped to the mobile examination centre where a label was placed on each aluminum container to allow respondents to record the exposure time (start date/time and end date/time). Every morning, based on the number of appointments for that day, staff at the mobile examination centre prepared the samplers, using cotton gloves and two wrenches. The hexagonal cap at the sampling end was replaced with the round polymer cap (white cap). The CHMS protocols contain detailed preparation procedures.¹² Once prepared, samplers were kept for no more than 7 days before being given to a respondent.

The indoor air component of the CHMS involved answering questions about the characteristics of the home and about the presence and use of potential sources of VOCs.¹⁶ At the mobile examination centre, respondents were given an indoor air sampler to take home and a demonstration of how to handle it. They were asked to deploy it for 7 days, starting the morning after their mobile examination centre visit. They also received an information sheet with detailed preparation and mail-back instructions and a toll-free phone number to call if they had questions (Appendix A). Respondents were called the morning after their mobile examination centre visit to remind them to deploy the sampler, and again, seven days later to remind them to mail it to the

Figure 1
Processing of indoor air samplers for 2009 to 2011 Canadian Health Measures Survey



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testing laboratory. If the laboratory did not receive the sampler within two weeks of the mobile examination centre visit, a combination of phone calls and letters was used to retrieve it.

At the testing laboratory, the samplers were inspected to verify that: the tube had been placed inside the aluminum container correctly; the exposure time was recorded on the label; and a respondent ID barcode label was on the canister. The respondent clinic ID, sampler ID, exposure time, sampler condition code, and comments were entered into the laboratory database.

There were 10 possible sampler condition codes (Table 1). Code 5 indicated missing exposure time. Because of the large number of samplers returned with code 5 during the first half of the collection period (sites 1 to 9), during the second half, Statistics Canada re-contacted code 5 respondents to try to obtain the missing information. If it was obtained, the concentrations of the com-

pounds were calculated, and the sampler condition code was set to 0. If exposure time information was not obtained, but the testing laboratory was able to make a reasonable assumption (for example, respondent entered the wrong year on the log sheet), the concentrations were calculated, and the condition code was set to 6. If the missing information was not obtained, and the testing laboratory could not make a reasonable assumption, the condition code remained 5.

Samplers coded 0, 1, 6, 7 or 9 were analyzed within 72 hours of receipt at the testing laboratory. Those coded 5 were also analyzed, but because it was not possible to calculate the concentration, the results were not reported. Samplers coded 2, 3, 4 or 8 were not analyzed.

The samples were analyzed using a PerkinElmer thermal desorber (Model: ATD650) and an Agilent gas chromatograph (Model: 6890) interfaced with an Agilent mass spectrometer (Model: 5975N) (Agilent Inc., Santa Clara, CA,

USA). Before being returned to the mobile examination centre, the tubes were inspected for defects and cleaned in an automatic tube desorber.

Quality assurance and quality control

Prior to the survey, Statistics Canada employees, in consultation with Health Canada and the testing laboratory, trained field operation staff in handling the samplers and in explaining the procedures that respondents were to follow when they took the samplers home. This training included a dress rehearsal, during which protocol and equipment problems were addressed. A retraining session was held mid-cycle, and staff were evaluated through periodic observations using standardized forms and guidelines.

To assess the performance of the analytical method and the testing laboratory, the testing laboratory performed laboratory blanks, duplicate samples, spiked samples, and calibration standards.

Table 1
Distribution of indoor air samplers returned to testing laboratory, by site and condition code, 2009 to 2011

Site	Total	Condition code									
		0	1	2	3	4	5	6	7	8	9
		According to protocol	White cap loose/not on sampler	Visible damage to sampler (not analyzed)	No results/Results not valid (not analyzed)	Envelope received without sampler	Impossible to recover time/date	Missing time/date imputed by testing laboratory	Mismatch of ID on metal container and sampler*	White cap at wrong end of sampler	Pencil found inside metal container
Total	4 581	3 661	98	6	19	5	504	150	24	87	27
1	297	226	10	0	1	0	55	3	0	1	1
2	271	203	8	0	0	1	48	10	0	0	1
3	256	187	8	1	0	0	48	9	0	3	0
4	282	186	6	0	3	0	46	35	2	1	3
5	237	200	5	0	0	0	26	5	0	0	1
6	267	164	4	0	1	1	31	9	0	56	1
7	278	234	1	0	0	0	38	2	0	2	1
8	268	214	3	0	0	0	39	11	0	1	0
9	265	228	4	0	1	1	20	11	0	0	0
10	283	253	6	0	0	0	10	6	2	1	5
11	205	180	1	1	0	0	9	6	7	0	1
12	203	175	5	0	0	0	14	4	2	0	3
13	251	203	5	0	0	0	23	9	5	4	2
14	283	249	2	1	1	0	16	2	3	6	3
15	227	171	13	0	0	0	31	4	2	5	1
16	212	172	4	1	0	1	21	10	1	0	2
17	262	226	5	2	1	0	18	5	0	5	0
18	234	190	8	0	11	1	11	9	0	2	2

* later resolved by Statistics Canada

Note: Excludes 106 samplers given to respondents and not received at testing laboratory and quality control samplers.

Source: 2009 to 2011 Canadian Health Measures Survey

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Two types of field quality control samples were also implemented: duplicates and blanks. Duplicates, a pair of samplers deployed at the mobile examination centre for 7 days as per respondent procedures, were used to evaluate the reproducibility of the analytical method. Duplicates were sent to the testing laboratory once a week. Two types of blanks—cleaning (also known as travel) and field blanks—were shipped to the mobile examination centre and handled by staff there to evaluate possible contamination of samplers in the survey. The cleaning blanks were tubes that were not opened at the mobile examination centre. The field blanks were tubes whose exposure end cap was changed to a white cap. Each week, staff at the mobile examination centre sent one cleaning blank and two field blanks to the testing laboratory. Duplicates and blanks were sent with no indication that they were control samplers rather than samplers from respondent households. A total of 82 pairs of duplicates, 173 field blanks and 75 cleaning blanks were com-

pleted; data from 79 pairs of duplicates, 173 field blanks and 74 cleaning blanks were valid. *T*-tests were used to compare the means of the field blanks and the cleaning blanks ($\alpha = 0.05$). Because the blank data were not normally distributed, a log transformation was applied to the data before performing the *t*-tests.

To determine the laboratory limit of detection (LOD), a known amount of a solution with a known chemical composition and concentration (a standard) were put in seven tubes and analyzed to find the lowest amount that could reliably be measured. Blank corrections were applied to a VOC when it was detected in 50% or more of the field blanks at values greater than the laboratory limit of detection.¹⁷ Respondent data were then adjusted by subtracting the median value of the field blanks from the measured amount, and the corresponding concentration was recalculated. Any resulting values below the laboratory limit of detection were coded "< LOD," in the same manner as values lower than the laboratory limit of detection that were

obtained for VOCs that did not require blank correction.

The field blank detection limit was calculated from the 173 field blanks as the arithmetic mean plus the standard deviation multiplied by the Student *t*-value at the 99% confidence level for a one-tailed test.¹⁸ The arithmetic mean and standard deviation were calculated from the log-transformed data, and the result was transformed back to the original scale to determine the field blank detection limit in the original units ($\mu\text{g}/\text{m}^3$). Because the field blanks were sent by data collection site, degrees of freedom equal to 13 ($df=13$) was used to account for the complex survey sample design,^{12,13} with a resulting Student *t*-value of 2.650. If the resulting field blank detection limit was lower than the laboratory limit of detection, the laboratory limit of detection value was used as the field blank detection limit.

Results

Of the 4,686 samplers distributed to CHMS respondents at the mobile examination centre, 4,581 (97.8%) were returned to the testing laboratory. The majority of the returned samplers ($n = 3,661$) were deployed and received according to the protocol (condition code 0) (Table 1). Results for 299 samplers coded 1, 6 or 9 were also reported to the CHMS by the testing laboratory. Results were not reported for 621 samplers coded 2, 3, 4, 5 or 8. Data from samplers coded 0, 1, 6, 7 or 9 that had an exposure time between 4 and 10 days ($n = 3,857$, 84.2% of all samplers received) were included in the CHMS indoor air data files.

Concentrations of the blank samples, specifically the geometric means, the medians and the field blank detection limits, are displayed in Tables 2, 3 and 4. General linear models showed no significant differences by site ($\alpha = 0.05$) for the field and cleaning blanks. Therefore, field and cleaning blank data were combined and not analyzed by site. The field blank and cleaning blank geometric means and medians were lower than $1 \mu\text{g}/\text{m}^3$ for 83 VOCs. The mean was significantly higher for the field blanks compared with the cleaning blanks for

Table 2
Volatile organic compounds with significant difference ($p < 0.05$) between field blanks and cleaning blanks, 2009 to 2011

Volatile organic compound	FDL ($\mu\text{g}/\text{m}^3$)	Cleaning blank (n=74)		Field blank (n=173)	
		Geometric mean ($\mu\text{g}/\text{m}^3$)	Median ($\mu\text{g}/\text{m}^3$)	Geometric mean ($\mu\text{g}/\text{m}^3$)	Median ($\mu\text{g}/\text{m}^3$)
Pentane	1.39	0.049	0.038	0.074	0.038
2-methyl-1,3-butadiene*	0.23	0.021	0.013	0.027	0.029
Acetone*	74.45	0.167	0.124	1.155	1.181
2-propanol*	65.42	0.131	0.055	0.748	0.782
2-methyl-2-propanol	0.19	0.020	0.020	0.027	0.020
2-butanone	0.33	0.024	0.019	0.031	0.019
Chloroform	0.05	0.007	0.007	0.008	0.007
Heptane	0.97	0.013	0.009	0.022	0.009
1-butanol	0.64	0.200	0.200	0.223	0.200
Trichloroethylene	0.12	0.008	0.007	0.011	0.007
4-methyl-2-pentanone	0.08	0.009	0.008	0.012	0.008
Toluene	2.13	0.112	0.082	0.160	0.082
Hexanal	1.81	0.111	0.091	0.156	0.091
<i>o</i> -xylene*	0.46	0.018	0.010	0.028	0.029
α -pinene	0.23	0.015	0.013	0.021	0.013
Cyclohexanone	0.09	0.038	0.038	0.040	0.038
Benzaldehyde*	3.74	0.048	0.060	0.149	0.171
Limonene*	2.58	0.045	0.017	0.097	0.105
Naphthalene	0.45	0.046	0.036	0.060	0.036

FDL = field blank detection limit

* field blank median value used for blank correction

Source: 2009 to 2011 Canadian Health Measures Survey

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19 VOCs ($p < 0.05$), particularly, acetone and 2-propanol, for which the geometric means were five to six times higher (Table 2). Of the remaining 65 VOCs, 28 were detected in blanks, but their means did not differ significantly between the field blanks and cleaning blanks (Table 3), and 37 were not detected in the field blanks or cleaning blanks (Table 4).

More than 50% of the field blank values for nine chemicals (benzaldehyde, benzene, 2-propanol, acetone, 2-methyl-1,3-butadiene, decane, ethylbenzene, limonene, o-xylene) were greater than the laboratory limit of detection, which indicated that they were candidates for blank correction. The field blank detection limits ranged from 0.01 $\mu\text{g}/\text{m}^3$ to

3.74 $\mu\text{g}/\text{m}^3$, except for acetone and 2-propanol, which had substantially higher field blank detection limits (74.45 $\mu\text{g}/\text{m}^3$ and 65.42 $\mu\text{g}/\text{m}^3$, respectively).

Reproducibility of the duplicates could not be assessed for 24 VOCs because no duplicate pairs had values greater than the laboratory limit of detection. Of the remaining 60 VOCs, 9 had a mean percentage difference between 0% and 10%; 37 were between 11% and 30%; and 14 were greater than 30%. Four VOCs had a mean percentage difference between the duplicate pairs greater than 40%: 2-furancarboxaldehyde, 1,1'-biphenyl, acetone, and 1-nonanol. However, the results for 1,1'-biphenyl and 1-nonanol were based on a small

number of duplicate pairs with detectable levels ($n = 5$ and $n = 1$, respectively). The mean percentage difference across all 60 assessed VOCs was 22%.

Discussion

The 2009 to 2011 CHMS was unique in that respondents themselves deployed the indoor air samplers in their homes and mailed them back to the testing laboratory. Almost all (99%) respondents who participated in the mobile examina-

Table 3
Volatile organic compounds with detectable levels but no significant difference ($p > 0.05$) between field blanks and cleaning blanks, 2009 to 2011

Volatile organic compound	FDL ($\mu\text{g}/\text{m}^3$)	Cleaning blank (n=74)		Field blank (n=173)	
		Geometric mean ($\mu\text{g}/\text{m}^3$)	Median ($\mu\text{g}/\text{m}^3$)	Geometric mean ($\mu\text{g}/\text{m}^3$)	Median ($\mu\text{g}/\text{m}^3$)
Hexane	0.92	0.090	0.076	0.104	0.076
1-propanol	0.06	0.029	0.028	0.030	0.028
Benzene*	0.70	0.092	0.099	0.086	0.098
2-pentanone	0.05	0.008	0.007	0.009	0.007
1,4-dioxane	0.02	0.007	0.006	0.007	0.006
Perchloroethylene	0.13	0.011	0.007	0.012	0.007
Ethylbenzene*	0.35	0.016	0.009	0.023	0.020
m-/p-xylene [†]	1.08	0.124	0.100	0.139	0.100
2-furancarboxaldehyde	1.07	0.113	0.078	0.129	0.078
Styrene	0.19	0.034	0.028	0.036	0.028
2-butoxyethanol	1.61	0.319	0.281	0.341	0.281
Cyclohexane	0.27	0.011	0.007	0.016	0.007
Octamethylcyclotetrasiloxane	0.63	0.176	0.164	0.190	0.164
Camphene	0.04	0.011	0.010	0.011	0.010
Decane*	0.66	0.040	0.036	0.042	0.046
1,2,4-trimethylbenzene	0.05	0.014	0.012	0.014	0.012
Octanal	0.38	0.040	0.032	0.047	0.032
1,4-dichlorobenzene	0.16	0.016	0.010	0.017	0.010
1,2,3-trimethylbenzene	0.17	0.019	0.012	0.020	0.012
2-ethyl-1-hexanol	0.56	0.111	0.111	0.123	0.111
Undecane	0.62	0.288	0.283	0.293	0.283
1-octanol	0.28	0.111	0.111	0.115	0.111
Decamethylcyclopentasiloxane	0.99	0.237	0.214	0.247	0.214
Nonanal	0.72	0.147	0.128	0.151	0.128
Dodecane	0.59	0.169	0.154	0.172	0.154
1-nonanol	0.29	0.123	0.123	0.126	0.123
Decanal	0.32	0.131	0.131	0.135	0.131
1,1'-biphenyl	0.06	0.013	0.011	0.013	0.011

FDL = field blank detection limit

[†] sum of m-xylene and p-xylene

* field blank median value used for blank correction

Source: 2009 to 2011 Canadian Health Measures Survey.

Table 4
Volatile organic compounds not detected in field blanks or cleaning blanks, 2009 to 2011

Volatile organic compound	FDL ($\mu\text{g}/\text{m}^3$)
Dimethoxymethane	0.13
3-chloro-1-propene	0.12
Nitromethane	0.19
Tetrahydrofuran	0.03
Tetrachlorocarbon	0.02
1,2-dichloropropane	0.02
Bromodichloromethane	0.01
1-pentanol	0.15
4-methyl-3-penten-2-one	0.16
Dibromochloromethane	0.01
1,2-dibromoethane	0.30
Ethanol, 2-methoxy-, acetate	0.37
5-methyl-2-hexanone	0.19
Ethanol, 2-ethoxy-, acetate	0.42
Cyclohexanol	0.16
Bromoform	0.15
Hexanoic acid, methyl ester	0.21
(1-methylethyl)benzene	0.02
Ethanol, 2-(2-methoxyethoxy)-	0.91
1,2-ethanediol, diacetate	1.01
Ethanol, 2-(2-ethoxyethoxy)-	1.02
(Chloromethyl)benzene	0.35
1,2-dichlorobenzene	0.02
Hexachloroethane	0.22
1-methyl-2-pyrrolidinone	0.15
Benzoic acid, methyl ester	0.17
2,4-dichlorotoluene	0.02
1-ethenyl-2-pyrrolidinone	0.16
3,5,5-trimethyl-2-cyclohexen-1-one	0.21
Benzoic acid, ethyl ester	0.22
2-nitrotoluene	0.20
3-phenyl-1-propanol	0.22
Quinoline	0.05
Benzoic acid, 2-methylpropyl ester	0.24
4-chloro-3-methylphenol	0.18
Benzoic acid, butyl ester	0.26
1,2-dimethoxy-4-(2-propenyl)benzene	0.25

FDL = field blank detection limit

Source: 2009 to 2011 Canadian Health Measures Survey.

tion centre component of the survey took a sampler home. The high percentage of samplers returned to the laboratory in a condition that met the survey's protocol (condition code 0) indicated that respondent deployment is a viable option for future national surveys.

It was anticipated that a certain number of samplers would be returned in compromised condition. A coding scheme was devised to document the nature and frequency of these deviations. Among the compromised samplers, substantial numbers were coded 5 (missing exposure times) or 6 (incomplete exposure times). Starting with site 10, Statistics Canada

instituted a call-back to respondents who returned code 5 samplers. As a result, the number of code 5 samplers fell from 351 at sites 1 to 9 to 153 at sites 10 to 18. Code 6 designated partially missing exposure time data that could be inferred by testing laboratory staff; for example, the month or year of deployment or the a.m./p.m. information was missing.

Codes 1, 8 and 9 pertained to the physical condition of samplers. Code 8 indicated that the wrong end of the sampler had been exposed to indoor air. This was the result of incorrect handling at the mobile examination centre before the samplers were distributed to respondents. At site 6, the percentage of code 8 samplers was large (56 out of 87), and likely reflected mishandling by a single staff member. Although the situation was quickly rectified, it demonstrated the importance of training staff in the field. Because the samplers were double-sealed (sealed sampler tube in a capped metal container), a tube with a loose or missing white cap (code 1) was still sealed in the metal container. Similarly, VOC emissions, if any, from the pencil that respondents received being placed in the metal container (code 9) would be unlikely to enter the tube during shipment from the respondent's home to the testing laboratory. Thus, for codes 1 and 9, sampler integrity was considered not to have been compromised.

Results of the field-deployed duplicates indicated good reproducibility of the analytical method. Of the VOCs for which reproducibility could be assessed, only 13 of 60 (22%) had a mean percentage difference between duplicate pairs greater than 30%. Data from a previous study reported a mean percentage difference greater than 30% for 14 of 33 (42%) VOCs.⁵ To avoid potential handling problems, duplicate samplers were deployed at the mobile examination centre instead of in respondents' homes. But because the indoor environments of these two locations differed, the prevalence of VOCs also differed. Consequently, reproducibility of some

VOCs that were present in residential homes, but not in the mobile examination centre, could not be assessed.

Sampler contamination could come from the cleaning process at the testing laboratory; during shipment; and from preparation at the mobile examination centre and in respondents' homes. Except for acetone, the geometric means and medians of all measured VOCs in both cleaning blanks and field blanks were $<1 \mu\text{g}/\text{m}^3$, indicating low levels of contamination. Given that the cleaning blanks were subject to only two of the three possible sources of contamination evaluated by the field blanks, it was expected that the concentrations would be lower or not significantly different in the cleaning blanks. This is what was observed: the geometric mean was either significantly greater for the field blanks compared with the cleaning blanks (18 VOCs), or not significantly different (66 VOCs).

The field blank detection limit is a reporting limit; values below the field blank detection limit may be a result of contamination. The field blank detection limits for acetone and 2-propanol were unusually high compared with the other 82 VOCs. The geometric mean of the field blanks was significantly higher compared with the cleaning blanks: $1.16 \mu\text{g}/\text{m}^3$ versus $0.17 \mu\text{g}/\text{m}^3$ for acetone, and $0.75 \mu\text{g}/\text{m}^3$ versus $0.13 \mu\text{g}/\text{m}^3$ for 2-propanol. Similarly, the median of the field blanks was significantly higher compared with the cleaning blanks: $1.16 \mu\text{g}/\text{m}^3$ versus $0.12 \mu\text{g}/\text{m}^3$ for acetone, and $0.78 \mu\text{g}/\text{m}^3$ versus $0.06 \mu\text{g}/\text{m}^3$ for 2-propanol. These findings suggest that preparation of the samplers at the mobile examination centre was a source of substantial contamination for acetone and 2-propanol. Thus, data for these two VOCs should be interpreted cautiously.

The duplicates and blanks were handled by field staff at the mobile examination centre. It is possible that the field quality control results would be different if these duplicate and blank samples had been handled by respondents in their homes.

What is already known on this subject?

- Many volatile organic compounds (VOCs) are more common indoors than outside.
- Indoor air is the largest contributor of human inhalation exposure to VOCs.
- VOCs in indoor air may have negative health consequences, ranging from mild irritation to more serious illnesses.
- Data about residential indoor air VOCs are needed to determine Canadian population exposure.

What does this study add?

- The indoor air component of the 2009 to 2011 Canadian Health Measures Survey provides nationally representative data for 84 VOCs, many of which have not been previously measured indoors.
- With these data, baseline levels for VOCs in residential indoor air can be established.
- Results suggest that it is feasible to conduct large-scale collection of residential indoor air VOC data by relying on respondents to deploy and return indoor air samplers.

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Conclusion

The indoor air component of the 2009 to 2011 CHMS provides nationally representative data for 84 VOCs, many of which have not previously been measured indoors. With these data, baseline

levels for VOCs in residential indoor air can be established. The high percentage of indoor air samplers returned in good condition demonstrated the feasibility of relying on survey respondents to deploy samplers in their homes. Field quality

control samples, namely, duplicates and blanks, indicated high quality of the indoor air VOC data collected. Thus, the sampling and analysis procedures used in this survey may be applied to future surveys. ■

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Appendix A

How to Use the Indoor Air Sampler

Day 1 [INSERT DATE HERE]

- In your living or family room in your home, locate a space for the sampler, at least 1.5 meters (5 feet) above the floor. An ideal location would be on top of furniture or a shelf that cannot be reached by children or pets. We want to make sure the sampler is not knocked down, preventing it from functioning properly.
- Rinse your hands with warm water and dry with a clean towel before opening the envelope.
- Open the aluminium container (2) and place all items on a clean surface. See Figure 2.
- Remove the white cap (B) and place it inside the aluminium container (2).
- Place the grey mesh cap (A) onto the brass tube (C) and make sure the cap is clipped into position.
- Place the tube upright at the chosen location with the grey cap pointed upwards.
- Using the pencil provided, write the starting date and time (to the nearest minute) on the label on the aluminium container.
- Make sure the container lid (1) is screwed on tightly. Store the container in the unsealed prepaid padded envelope and put the pencil in the envelope. Place the envelope at least 30 cm (1 foot) away from the tube to allow the sampler to function properly.

IMPORTANT:

Please make sure that the dates and times of the start and end of sampling are clearly written on the label of the container.

If you have any questions, please call toll-free 1-888-253-1087.

Note: Please return the sampler even if it has been moved, damaged, or set up for a period other than seven days.

Do:

- Keep the sampler upright in the same location. If it gets knocked over, return it to its original position.
- Send the sampler back as soon as the collection period ends, in the envelope provided.
- Write the date and time when you begin sampling and the date and time when you finish.

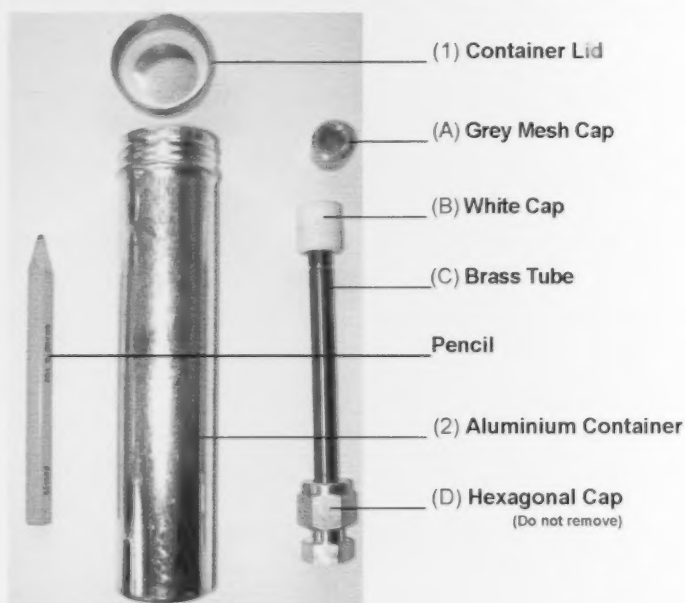
Do NOT:

- Do not use soap when you wash your hands before handling the sampler.
- Move the sampler location during the seven-day collection period.
- Throw away the aluminium container as it is needed to return the sampler undamaged.

Day 8 [INSERT DATE HERE]

- Rinse your hands with warm water and dry with a clean towel.
- Remove the sampler from the chosen location.
- Remove the grey mesh cap (A) and recap the tube with the white cap (B) found in the aluminium container (2) inside the envelope.
- Using the pencil provided, record the end date and time (to the nearest minute) on the label on the container.
- Put the capped brass tube inside the aluminium container with the white cap pointed upwards.
- Put the grey mesh cap in the container and screw the container lid (1) on tight.
- Put the container inside the prepaid padded envelope. You do not need to return the pencil.
- Place the sealed prepaid padded envelope (addressed to CASSEN Laboratories) in any Canada Post mailbox as soon as possible.

Figure 2
Indoor air sampler components



CAUTION: Keep out of reach of children.
This unit contains small parts that may be harmful if swallowed.